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An Econometric Analysis of the Short Run Philips Curve: Is it still relevant in today's context?

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Abstract

The Phillips curve is generally been estimated in a linear framework, which implies a constant relationship between inflation and unemployment. Lately, there have been several studies, which claim that the slope of Phillips curve is function of macroeconomics conditions and that relationship is asymmetric. In this paper, we want to test the negative relationship between inflation and unemployment for the United State It turn out that the Phillips curve of United State is still relevant in today context.

Keywords: Phillips Curve, adaptive expectations, rational expectations, instrumentals variable, Inversed Phillips Curve.

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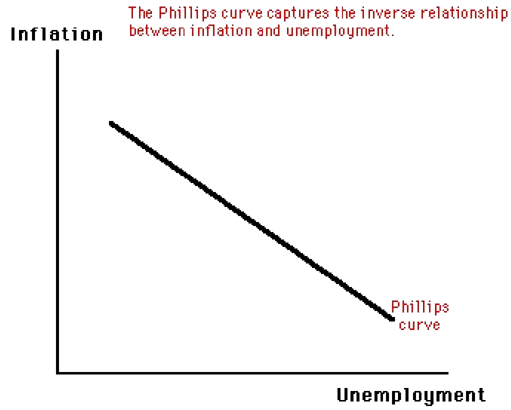
1. Introduction

The shape of the Phillips curve is central in conducting monetary policies. Many empirical models of the Phillips curve for US are heavily influenced by the work of Gordon (1970, 1975, 1977, 1983, and 1997). His preferred Phillips curve specification is linear with backward looking inflation expectation .He allows for a kinked functional form and finds no significant evidence of non-linearity and therefore conclude that the Phillips curve is resolutely linear. Despite that, there has been many non-linear Philip curve estimated for US.

In this paper, the expectation augmented Phillips curve will be reconsidered. The focus is on investigating the relationship between the inflation rate and unemployment in a linear setting.

The paper is organized as follows. After some exposition of historical and theoretical background in section 2, the simple adaptive model where j=1 are introduced in section 3. Next, we use the rational expectation hypothesis to refine the expectation augmented Phillips curve in our next section. Then in the last section, we use the oil price shocks as the Instrumental Variable (IV) for inflation to measure the negative relation between inflation and unemployment rate (in term of inverse Phillips curve).

2. Background

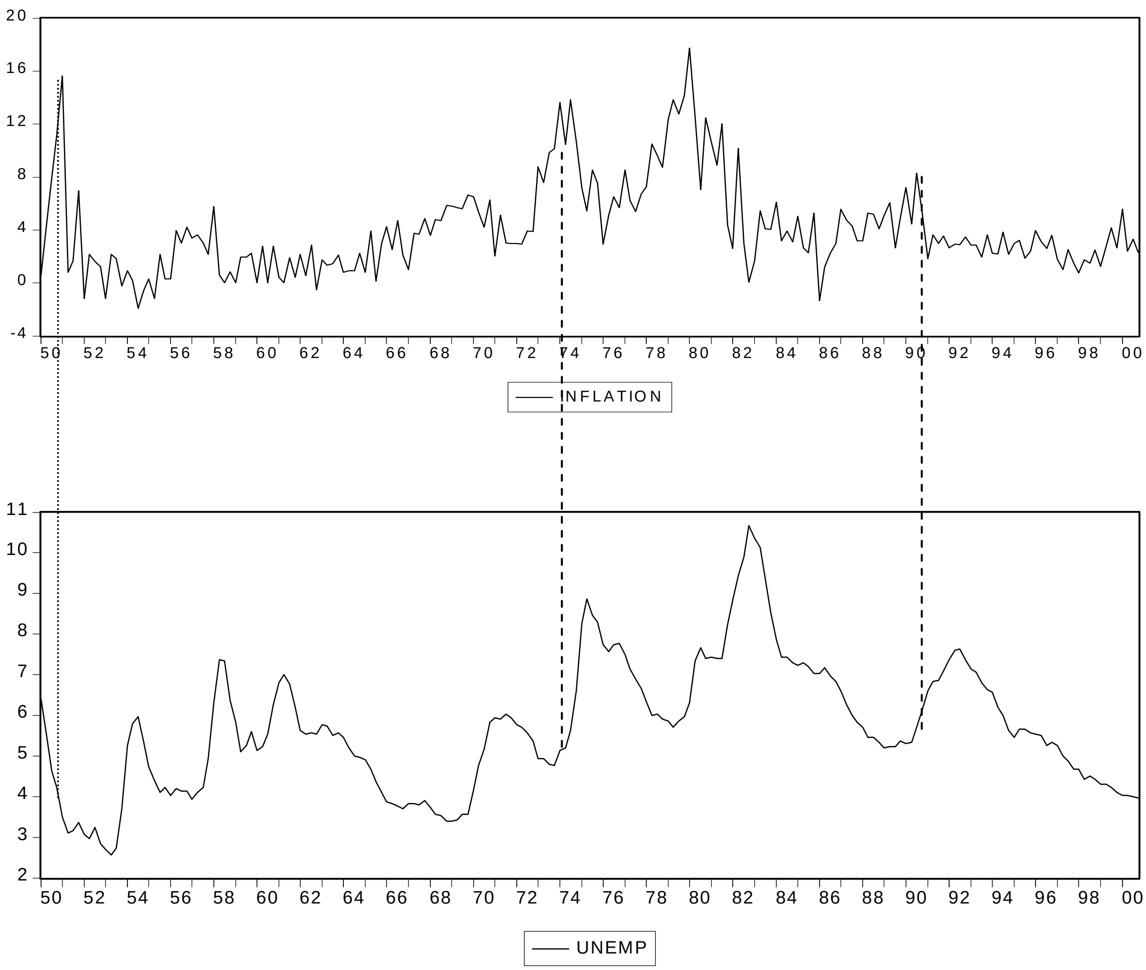


In his seminal paper, Phillips found a negative relationship between unemployment and wage inflation in UK for the time frame of 1861-1957. Subsequent research also found a similar relationship between unemployment and price inflation. This relationship has since been known as the Phillips curve and at that time there was strong empirical support for a stable inflation-unemployment trade-off. In the early 1970s, the first empirical failures of the Phillips curve occurred when both inflation and unemployment increased simultaneously, primary due to the oil-price shocks. The critique prompted the formulation of the expectation–augmented Phillips curve. According to this specification no policy can permanently lower unemployment below its natural rate unless expectations are highly irrational.

The Phillips curve is regaining interest after a period in neglect and there has been considerable theoretical work suggesting a non-linear relationship between inflation and unemployment. This is so called “new Philips curve”. However, the shape of non-linearity is ambiguous since the different theories yield different non-linear relationships.

2.2. Data

The time-series data are seasonally adjusted quarterly data covering from the period 1950: Q1 – 2000: Q4. The inflation measure used is annual changes in CPI and the inflation expectations are given by measure of expected inflation over the next year held at period *t*. On the other hand, the measure of unemployment rate uses the number of unemployed (effective) labour over the total labour forces[1].



The Federal Reserve formally opened its disinflationary policy in October 1979 and inflation has been reversed and stabilized after the peak in 1981.The time series-series move closely together during the whole sample and there are no systematic

[1] All data are collected from the www.economagic.com

discrepancies. Besides, the figures above shown that there are indeed a trade off between the unemployment and inflation (as shown by three dotted lines above) that is, when the inflation is high, it is followed by a low unemployment rate and vice-versa. However, this relationship does not hold after the year 1992 as the unemployment rate keep on falling down no matter the inflation rate changes.

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3. The Expectation-augmented short run Phillips curve

A linear expectations-augmented short-run Phillips curve is typically assumed to be of the following form:

$$\pi_t - \pi_t^e = -\beta(\mu_t - \overline{\mu}_t) \quad (2.1)$$

where μ_t is the natural rate of unemployment and π_t^e is the expected rate of inflation form in year *t-1*.This model assumes that the natural rate is constant. The difference between actual unemployment and the natural rate $(\mu_t - \overline{\mu})$ is called cyclical unemployment, while the difference between actual and expected inflation $(\pi_t - \pi_t^e)$ is called unanticipated inflation .If there is a trade of between unanticipated inflation and cyclical unemployment then β <0. Besides, it measures the strength of the relationship between unanticipated and cyclical unemployment.

To complete this model, we need to make an assumption about inflationary expectations. We assume that the expectations of inflation (π_t^e) are formed using the

1. Rational expectation $\pi_t^e = j\pi_{t-1} + (1-j)\pi_{t-1}^e$ where 0<j<1 or

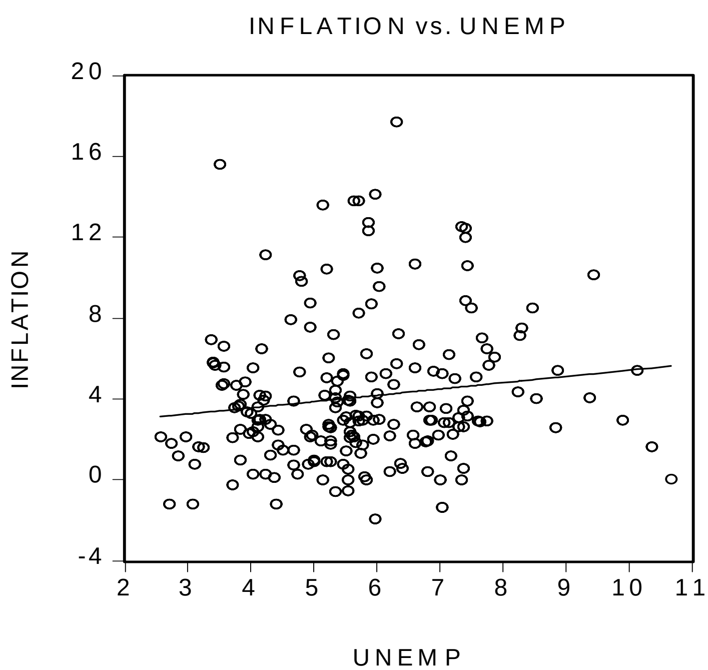
2. Simple adaptive expectation as of last period's actual inflation rate (π_t), which is: $\pi_t^e = \pi_{t-1}$ where j=1

If we are using the simple adaptive model to estimate a linear Phillips curve, we can write

$$\pi_t = \beta\mu + \pi_t^e - \beta\mu \tag{2.2}$$

where the expectation augmented Phillips curve relates the inflation to the level of unemployment and expectation inflation of past year .Hence, the estimated equation for the United State for the period 1950(1) to 2000(4) is

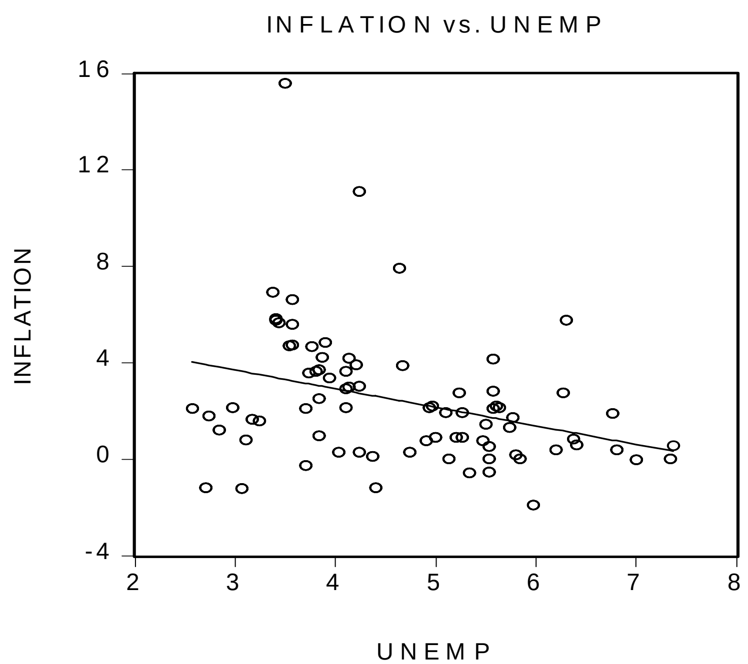
$$\pi_t = \underset{(0.645898)}{1.0847} + \underset{(0.01358)}{0.013581}\mu_t + \underset{0.049856}{0.717782}\pi_{t-1}^e$$



Given the result above, the inflation rate is positively related to the expectation inflation because t statistic is significantly high at 5% significant level. However, the unemployment rate was not negatively correlated with the inflation rate as theory mentioned. Besides, t-statistic is also insignificant.

In order to find out more meaningful of Philip curve, we divide the 50 year period into two parts, which are, from 1950(1) to 1969(4) and 1970(1) to 2000(4).

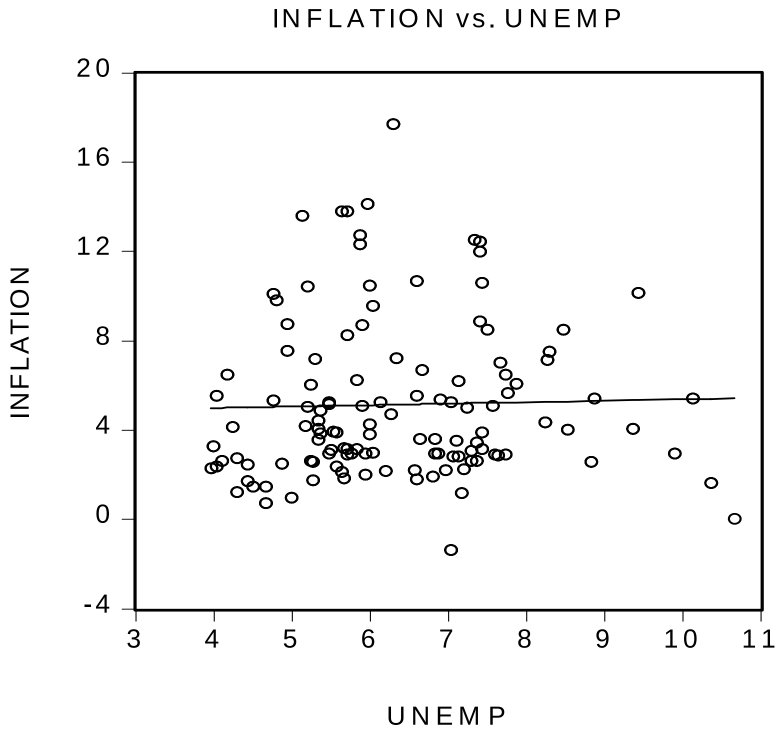
1). 1950:1 to 1969:4



$$\pi_t = \underset{(1.2933)}{3.5018} - \underset{(0.2494)}{0.435968}\,\mu_t + \underset{(0.1074)}{0.405861}\,\pi^e_{t-1}$$

The experience of US economy from 1950(1) to 1969(4) seemed to confirm the hypothesis that there was a trade off between inflation and unemployment because the above result gives a significant result for both variable where inflation and unemployment rate are negatively related and gives a significant t- value at 10% significant level. Besides, the expected inflation is shown to have positively related to the inflation rate.

(2). 1970:1 to 2000:4



$$\pi_t = \underset{(0.9927)}{2.026} - 0.1278\mu_t + \underset{(0.0605)}{0.7585}\pi^e_{t-1}$$

However, the confidence of policymakers in the inflation and unemployment trade off was shattered after 1970.The data simply refused to cooperate and lie along a stable Phillip curve. Instead the relationship between inflation and unemployment went “out of kilter”. This can be shown in the above analysis as the unemployment no longer significant although the F-statistic shown a joint significance.

4. Rational expectations

We will now model our expectations-augmented Phillips curve using rational expectations. So what are rational expectations?

According to Lucas, the rational expectation hypothesis suggests that the public forecasts future economic magnitudes (e.g. inflation) with all available data. Moreover, the people do not consistently make the same forecasting mistakes. One of the most common forms of expectations is the adaptive expectations. Simply speaking, it refers to the adjustment of expected values for next year period (in this case, inflation) based on the average of actual values in the preceding periods.

We will use adaptive expectations using the fitted values of inflation rates (π_t^e) obtained from the preceding AR (3) process to determine *j*. *j* lies between 0 and 1.
Under simple adaptive expectations,

$$\pi_t^e = j\pi_{t-1} + (1-j)\pi_{t-1}^e$$

The numerical value of *j* determines how the previous actual inflation rates (π_{t-1}) and expected inflation rates last quarter (π_{t-1}^e) impact on the current expected inflation (π_t^e).

4.1. Stationarity

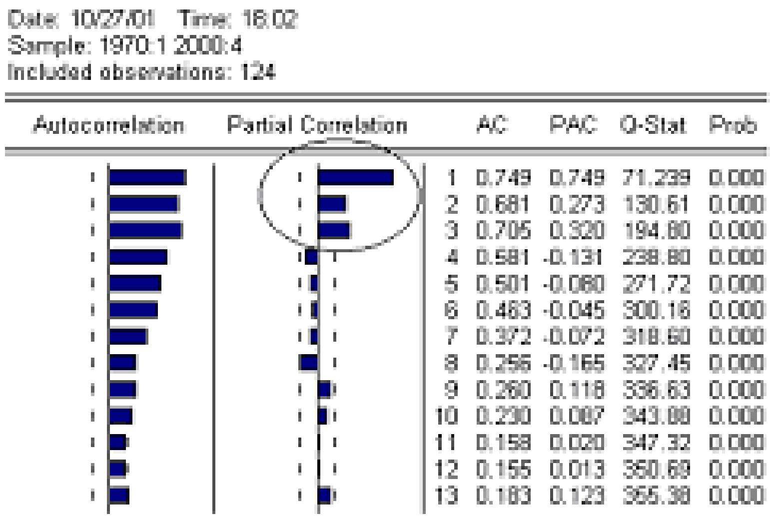
A **stationary** stochastic process occurs when its mean and variance are constant over time and the covariance between two time periods depends only in the distance or lag between the periods and not on the actual time at which the covariance is computed. The chief tools to test for stationarity are (1) **autocorrelation (AC)** and (2) **partial autocorrelation function (PAC)**.

The ACF at lag *k*, denoted by p_k, is defined as:

$$p_k = \frac{covariance\ at\ lag\ k}{variance}$$

It lies between 0 and 1.

Partial autocorrelation on the other hand measures correlation between observations that are *k* time periods apart after controlling for correlations at intermediate lags. A plot of these two tests against lags is displayed at the **sample correlogram** below. We used U.S. quarterly inflation rates as the variable from 1970 to 2000.


Date: 10/27/01 Time: 16:02
Sample: 1970:1 2000:4
Included observations: 124

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.749	0.749	71.239	0.000
		2	0.681	0.273	130.61	0.000
		3	0.705	0.320	194.80	0.000
		4	0.581	-0.131	238.80	0.000
		5	0.501	-0.080	271.72	0.000
		6	0.463	-0.045	300.16	0.000
		7	0.372	-0.072	318.60	0.000
		8	0.256	-0.165	327.45	0.000
		9	0.260	0.118	336.63	0.000
		10	0.230	0.087	343.88	0.000
		11	0.158	0.020	347.32	0.000
		12	0.155	0.013	350.69	0.000
		13	0.183	0.123	355.38	0.000

AR (3) process:

$$\hat{\pi} = 0.4846\pi_{t-1} + 0.1209\pi_{t-2} + 0.357\pi_{t-3}$$

(0.0858) (0.0962) (0.0855)

(5.645) (1.2565) (4.1737)

R-squared	0.634407
F-statistic	69.78443

This shows that the inflation follows an AR (3) process. The above ordinary least regression result tells us that the dependent variables are individually significant (refer to *p* values) except for π_{t-2} and jointly statistically significant for all three variables (*p* value = 0.0003).

We'll now take the fitted inflation values ($\hat{\pi}$) from this result to model the rational expectations hypothesis, replacing π_t^e with these fitted values.

From 1971 Q1 to 2000 Q4:

$$\pi_t^e = 0.4827\pi_{t-1} + (0.4939)\pi_{t-1}^e$$
$$(0.0264) \qquad (0.0282)$$
$$(18.273) \qquad (17.53625)$$

R-squared 0.960580

In this period of time, the 2 dependent variables are also highly statistically significant. As expected, the coefficients of these 2 variables add up to 0.976728 which is roughly 1. *j* is even higher, calculated at a value of 0.482782.

4.1.1. Insight

Scenario: Why does j differ from one time period

i.e. 1950-1970 and 1971-2000?

1950-1969

$$\pi_t^e = 0.39774\pi_{t-1} + 0.541913\pi_{t-1}^e$$
$$(0.0163) \qquad (0.0215)$$

1970-2000:

$$\pi_t^e = 0.4828\pi_{t-1} + 0.4939\pi_{t-1}^e$$
$$(0.0264) \quad (0.0281)$$

Economic intuition:

As the figures show above, *j* has changed considerably over the years, from 0.397737 to 0.482782. So what contributes to a higher *j*? As explained before, this is attributed to the efficient and the collation process of economic data by the U.S. economic agencies over the years especially in the latter period. Thus, the public is able to retrieve the information instantly and forecast the expected inflation better and easier.

We substitute the rational expectations hypothesis into the Phillips curve to derive a new Phillips relationship.

$$\begin{array}{ccccccc} \pi_t & = & 2.794 & - & 0.3793\,unemp & + & 0.9564\pi_{t-1}^e \\ & & (2.7945) & & (0.1369) & & (0.06277) \\ & & (3.1698) & & (-2.7712) & & (15.237) \end{array}$$

R-squared	0.663338
F-statistic	116.2501

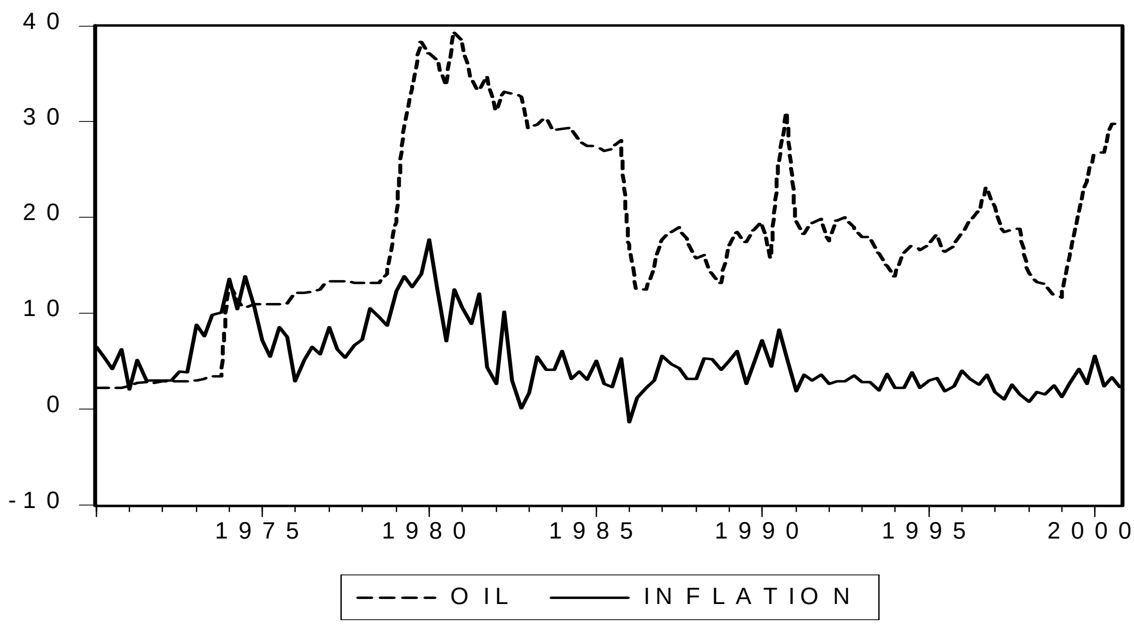
$\beta_0 = -\beta_1 \mu_0$

μ_{0}=7.367.

In this model, the natural rate of unemployment is overestimated. However, to refine the model even more, we will introduce oil price as an instrumental value in the next section.

5. Oil prices as an Instrumental Variable (IV) for inflation.

In this section, we will employ the techniques of Instrumental Variable (IV) to refine from 1970: Q1 to 2000: Q4.



We have mentioned in the earlier part of the report that the first empirical failures of the Phillips curve occurred when both inflation and unemployment increased simultaneously, primary due to the oil-price shocks. As can be seen in the above diagram, oil prices and inflation have positive relationship. Therefore, we will introduce Oil prices as an IV for inflation.

In order to have a qualified variable as an Instrumental Variable (IV), it must have two conditions:

1. It must partially correlates with the endogenous explanatory variable.
2. It must be exogenous, that is, uncorrelated with the error term of the structural equation;

In our case study, we choose oil prices as IV for fitted inflation rates. So, do oil prices fulfill the conditions as an IV? We shall now go through the above conditions imposed to determine its suitability.

5.1. Correlation with endogenous variables

A simple ordinary least square was performed. A correlogram (of oil prices) was also developed and realized that oil prices follow the model of AR (1) process. Hence we regress prices of oil at 2 time intervals, one after the other.

$$\pi_t^e = 0.5297OIL - 0.4780OIL(-1) + 4.071$$

(0.52979)	(–0.47808)	(0.6467)
(6.2954)	(5.000)	(6.2954)

R-squared 0.176182

The table displayed that the 2 independent variables, OIL and OIL (-1) was individually statistically significant. This shows that they are correlated with explained 20%of the changes in inflation.

5.2. Uncorrelated with the error term

Oil and Oil (-1) must be uncorrelated with the error term. Using the test for over-identifying restrictions, where the H_o means that all IVs are uncorrelated with residuals (calculated from 2 stage least square), we realized that nR^2 (0.0217 X 121) which is less than the critical of X (3.84). Hence, we cannot reject H_o and all IVs are exogenous.

Based on economic intuition, oil prices should not have a direct effect to unemployment rate. It affects unemployment rate indirectly through the effect on inflation rate. In addition, oil prices are unpredictable (exogenous), hence it should not have an effect on the disturbance terms as well.

Therefore, after fulfilling the 2 conditions, we can conclude that the prices of oil have passed the test for an IV.

Later, we derive the inverse Phillips curve with unemployment as dependent variable so that oil as an IV can be employed. The following method is as followed:

$$\pi_t - \pi_t^e = \beta(u_t - \bar{u})$$

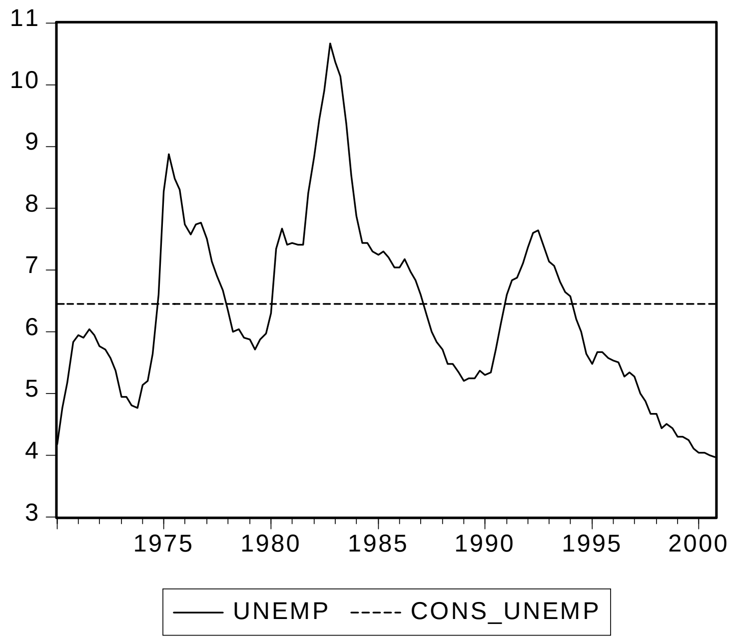
$$\frac{\pi_t - \pi_t^e}{\beta} = (u_t - \bar{u})$$

$$u_t = \bar{u} + \gamma(\pi_t - \pi_t^e) \qquad \textit{where } \gamma = \frac{1}{\beta}$$

Using 2 stage least square method, we found the following results.

$$\hat{\mu}_t = -\underset{(-3..31)}{\underset{(.1256)}{0.416}}\Delta\hat{\pi} + \underset{(47.590)}{\underset{(0.1354)}{6\,.447}} \qquad \ldots\ldots\ldots(4)$$

From this result, we found out the independent variables are both statistically significant and having the natural rate of unemployment of 6.44%. This is roughly the same as the mean unemployment rates calculated over the past few years as shown in the time series diagram below.



Mean	6.340855
Median	6.000000
Maximum	10.66700
Minimum	3.967000
Std. Dev	1.433010
Skewness	0.665117
Kurtosis	3.301809

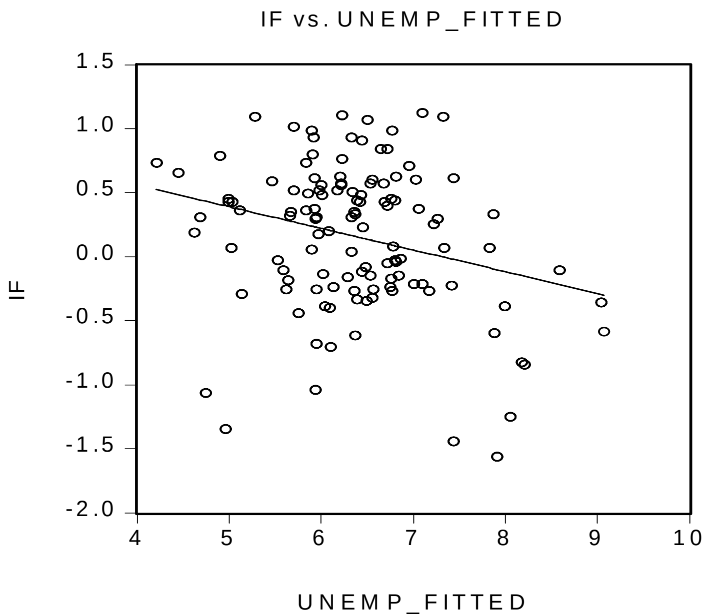
6. CONCLUSION

We later re-inverse back the Phillips curve, plotting the change of inflation rates (y axis) against unemployment. Mathematically speaking, this is expressed as below:

$$u_t = \overline{u} + \gamma(\pi_t - \pi_t^e) \qquad where\ \gamma = \frac{1}{\beta}$$

$$\gamma(\pi_t - \pi_t^e) = u_t - \overline{u}$$

$$IF = -\beta_0\overline{u} + \beta_1 u_t$$



After incorporating oil prices as IV and using rational expectations hypothesis to refine the expectations-augmented Phillips curve, we have found out that the relationship between inflation and unemployment remains negative! This is akin to 1950-1969 period. Thus we conclude the Phillips curve still remains valid in today's world.

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Statistical Software Eviews 3.0

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Appendix 1

Regressions Output

(1)

Dependent Variable: INFLATION
Method: Least Squares
Sample(adjusted): 1970:4 2000:4
Included observations: 121 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INFLATION(-1)	0.484620	0.085846	5.645255	0.0000
INFLATION(-2)	0.120892	0.096208	1.256568	0.2114
INFLATION(-3)	0.357118	0.085563	4.173738	0.0001
R-squared	0.634407	Mean dependent var	5.137917	
Adjusted R-squared	0.628211	S.D. dependent var	3.564084	
F-statistic	69.7694478443	Prob(F-statistic)	0.000000	

(2)

Dependent Variable: FITTED
Method: Least Squares
Sample(adjusted): 1971:1 2000:4
Included observations: 120 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
INFLATION(-1)	0.482782	0.026419	18.27428	0.0000
FITTED(-1)	0.493946	0.028167	17.53625	0.0000
R-squared	0.960580	Mean dependent var	4.980742	
Adjusted R-squared	0.960246	S.D. dependent var	3.121087	

(3)

Dependent Variable: INFLATION
Method: Least Squares
Sample(adjusted): 1970:2 2000:4
Included observations: 123 after adjusting endpoints

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	4.070988	0.646660	6.295404	0.0000

OIL	0.529794	0.105957	5.000076	0.0000
OIL(-1)	-0.478084	0.105313	-4.539651	0.0000

R-squared	0.176182	Mean dependent var	5.131894
Adjusted R-squared	0.162452	S.D. dependent var	3.535812
Log likelihood	-317.4503	F-statistic	12.83164

(4)

Dependent Variable: UNEMP
Method: Two-Stage Least Squares
Sample(adjusted): 1970:4 2000:4
Included observations: 121 after adjusting endpoints
Instrument list: C OIL OIL(-1)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.446857	0.135465	47.59059	0.0000
INFLATION-FITTED	-0.416245	0.125609	-3.313817	0.0012

R-squared	-0.060847	Mean dependent var	6.381529
Adjusted R-squared	-0.069761	S.D. dependent var	1.425371